3. Telecommunication Networks

3.1. Network Planning

Before any network can come into operation, it has to go through several stages to ensure that it conforms to certain standards; meets the requirements of the user; and is feasible. For a network to successful it has to go through a detailed stage of planning. The key part of planning involves the identification of investment required for the network, in the form of a budget and timelines. Planning is one of the key areas of networks management and any network designed without proper planning is bound to spectacularly fail. A typical example is the South African electronic national transport system (e-Natis), which was delivered way beyond its planned date, exceeded its budget and had problems after its launch due to too much traffic. So, network planning is a crucial process, which involves calculating the capacity needed for the services to be provided on the network and the cost-effectiveness of doing the operations [1]. The results of network planning are used as a basis for the operator's decisions about investments in the necessary resources for traffic and network management.

Investment in telecommunications networks is based on the layering of the network discussed in Chapter 1 of this manual. According to the network model used, every layer requires its own investment as follows: management, supervision and control; network intelligence; switching and signaling; transport; access network; customer premises equipment. From the management perspective, key investment is required to acquire the equipment (hardware and software) needed for the actual process of network management, plus all other processes associated with network management. In addition to equipment, personnel are required to operate the equipment and analyze the collected data. Equipment plus personnel are also required for intelligence in the network. The equipment include: databases, control computers, etc. All the others layers as well require investments in the form of both labor (skills) and equipment (hardware and software). One of the major changes is that the cost of personnel has far outweighed the cost of equipment; while conventionally the cost of equipment was higher, but the falling of investment costs per km in the transport layer plus the relative increase of processor power for lower prices have facilitated this change. The land where the equipment is going to be housed needs to be leased or bought by the operators, which involves increased costs.

3.1.1. Life Cycle Cost (LCC)

When acquiring equipment, operators have to consider several costs for the lifespan of their equipment. These costs include costs of operation and maintenance, service, upgrade and replacement costs. Now with the current shortage of energy (electricity) in Southern Africa, the resulting power outages (load shedding) has resulted in more damaged equipment and the reduced lifespan for most equipment and has demanded more investment in power

protection equipment such as UPSs, surge protectors, etc. Also the global fight against terrorism and child pornography places more requirements from the networks to effectively filter unwanted content and to trace the perpetrators, thus increasing the cost of equipment due to the need for sophisticated filters needed plus monitoring capabilities. Most governments including Lesotho and Zimbabwe now require telecommunications equipment installed in their countries to have interception and monitoring capabilities. All these means more investment is required than ever before. Adding all these costs to the acquisition cost of equipment form what is referred to as: "*Life Cycle Cost*" [1] of the equipment.

Life Cycle Cost (LCC) consists of the following components [1]:

a) Investment Costs: Direct costs of production, research and development, procurement, transport, assembly, and testing
b) Network Management Costs – training, testing, upgrading, fault correction, allocation of network resources, customer service, storage, power, rent for sites and buildings, technical descriptions of network management procedures, transport, etc.
c) Phasing Out Costs – dismantling and scrapping.

The LCC concept should also include the residual value, if any: the possibility of reuse, or the scrap value [1]. The current surge in the number of companies selling refurbished computers is an example of getting something after the life cycle of computers. The cost of handling hardware is not evenly distributed over the lifespan of the equipment, instead more costs are involved initially (*teething troubles*) and at the end (*infirmities of old age*) [1], as shown by figure 3.1.

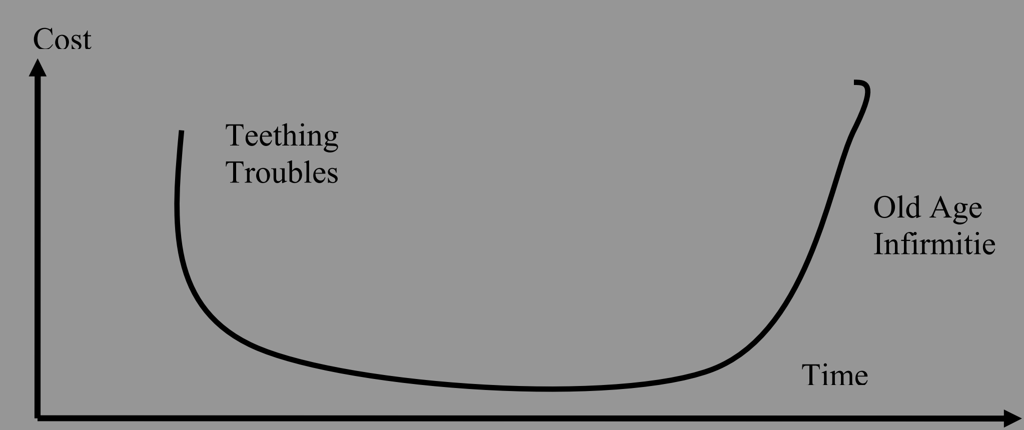

Figure 3.1 [1], shows Cost of Handling Hardware

Equipment should be phased out before the infirmities of old age settle in, and it becomes expensive and cumbersome to update the equipment. Also once the functionality becomes outdated, which occurs quite rapidly in telecommunications field and the equipment no longer performs according to standards and expectations.

3.1.2. Market Plan

The key aim of telecommunications networks is to satisfy the market need for a certain service. With this in mind network planning must include the necessary market need and analysis, thus showing the revenue of the operator. Where is the money going to come from? A key element in the market plan is the operator's business concept, and the role or niche that goes with it [1]. Is the operator a converged one or not? Is the operator a service provider or a network operator or both? Which services and traffic are of interest: video, voice, data or multimedia? Part of the market plan is the product plan, which covers the actual complete communication service to be offered by the operator to the consumer. Different types of consumers require different types of services, thus forcing operators to model services according to the target group. Consumers can be broadly divided into two (2) categories: Business and Residential. According to [1], a category of Society can be added to form three categories of consumers. Based on these categories of consumers, operators have to make rough estimates of the volumes of different services and their pricing. Also included in the product plan are the requirements for quality of service, time of delivery and pricing.

3.1.3. Technology Plan

The rate at which technologies are becoming obsolete is putting a lot of strain on telecommunications operators. Which technology to opt for – today or future? Technological development is driven by the general desire for improved performance (giving customers "good value for their money" by reducing: size, power consumption and price) [1]. There are also other factors such as increased demand for mobility, increased utilization of the already installed media such as copper (ADSL, VDSL, etc) and power cables (BPL, PLC). When deciding on which technology to adopt for the network, several factors have to be considered including: affordability, scalability, security, transmission speed, reliability, convergence, mobility, broadband capability (i.e. triple play capable), etc. Several methodologies can be used when selecting which technology to use including: Cost-Benefit Analysis and SWOT [3] analysis. With cost-benefit analysis, operators mainly concentrate on the cost savings of adopting one technology over the other; while with SWOT analysis; operators compare technologies based on their strengths (S), weaknesses (W), opportunities (O) and threats (T). The following extract from [3], aims to show how SWOT can be applied, and is meant only for CS5440 students.

4.1.8. SWOT Analysis for VDSL and PLC

The SWOT analysis for both VDSL and PLC is carried out to further assess which technology has many benefits, fewer weaknesses, more opportunities and fewer threats to its existence and adoption as the access technology of choice in broadband access networks; such is a technology of choice for West Campus BRAN. SWOT defines the strengths (S), weaknesses (W), opportunities (O) and threats (T).

Technology	Strengths (S)
VDSL	Fast data rates with fiber-like speeds, hence suitable for full-services Reuses existing copper plant, hence minimizes initial capital investment Easy to install and commission by any qualified telecoms technician Less disruption to residents' homes and fast time to revenue Highly secure as it's a point-to-point architecture
PLC	Reuses existing electricity cables, hence minimizes initial investment Less disruption to residents' homes Fast time to revenue
	Weaknesses (W)
VDSL	Short distance coverage, with speeds decreasing with increases in distance Not yet available in SA, hence no legislation in SA as yet Viewed as an intermediary solution for the ultimate fiber-to-the-home solution
PLC	Very hostile medium not suitable for broadband services and full-services Less secure and less throughput as it's a shared medium architecture Distance-limited with repeaters every *300*m, hence very expensive By-passing transformers is expensive Expensive equipment and need for skilled heavy-current technicians No business case yet Not yet popular with other technologies having an advantage over it No legislation in SA as of yet
	Opportunities (O)
VDSL	Broadband access solution for residential and business customers Interim solution for eventual fiber-to-the-home (FTTH) Suitable for densely populated areas and urban areas
PLC	Access solution for residential and business customers In-house networking solution Viable option where there is no copper and other access technologies Suitable for sparsely populated and rural areas with electricity
	Threats (T)
VDSL	Two technologies (FTTH and Wi-Fi) pose a threat to VDSL
PLC	Several other technologies including VDSL, ADSL, DSL Wi-Fi, FTTH, WiMAX, and cable-TV pose a threat to PLC Opposition from amateur radio operators worldwide due to its interference with licensed radio services

Table 4.1 shows the SWOT analysis for VDSL and PLC

3.1.4. Network Development Plan

The network development plan involves factors that affect the target network in terms of long-term investments. These factors include [1]: architecture and segmentation of traffic carrying network; choice of technique; fundamental technical plans and network management. At this stage the design of the network can be drawn and the rules used for this design are called fundamental technical plans and apply to a number of important areas [1]:

a) Numbering Plan – shows how trunk codes and subscriber numbers are composed. Numbering plan gives each subscriber and service a unique code which makes automatic call setup possible. In addition to its support for call setup, route selection in exchanges and interworking between bearer networks, it also forms the basis for call charging.
b) Transmission Plan – stipulates quality requirements and technique for the transmission of teletraffic. In analogue communications, the main focus was on "transmission loss plan", which defines the degree to which the signal is allowed to be attenuated on its way between subscribers. This has completely been eliminated with digital communications.
c) Routing Plan – regulates routing between exchanges, and describes the design of the bearer network and its use for traffic and stipulates rules for: structure of the network; traffic routing; gateways; etc.
d) Signaling Plan – defines the information that must be exchanged between nodes when connections are setup.
e) Synchronization Plan – stipulates rules that must be followed to prevent digital exchanges in the network from falling out of synchronization
f) Charging Plan – specifies the basic principles of charging for traffic and services. Fees may be set as follows: installation fees; subscription fees; usage fees.
g) Network Management Plan – defines quality of service objectives and hence, requirements for grade of service, transmission performance and availability.
h) Frequency Plan – stipulates rules for network operator's use of available frequency bands.

The fundamental technical plans provide invaluable support in the procurement of equipment, in the parameterization of software and when equipment is put in operation; and figure 3.2, shows their relationships.

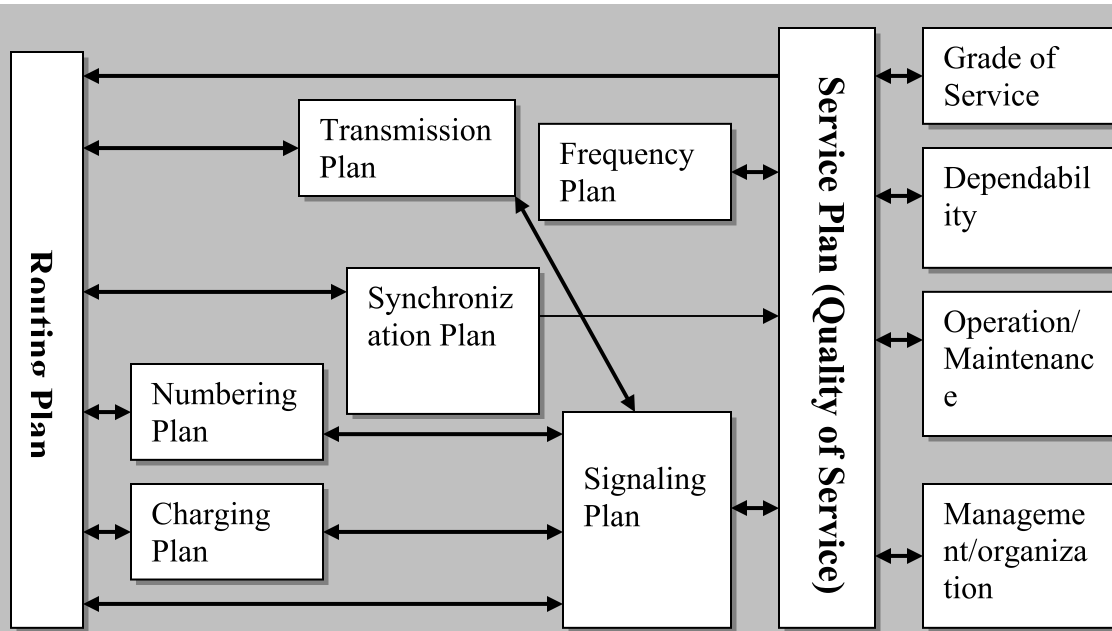

Figure 3.2 [1], shows Relationships between fundamental technical plans

3.1.5. Dimensioning

Network dimensioning helps operators to anticipate the traffic flow on their networks. This may be achieved by dividing subscribers into different groups based on their expected or forecast usage. Dimensioning ensures that expected needs of the telecommunications network will be met in an economical way, both for subscribers and operators. In addition, future sources of traffic have to be anticipated as well as the expansion of the network to accommodate more subscribers and more new bandwidth-hungry applications.

To simplify dimensioning, segmentation of user categories may be helpful [1]:

a) Residential subscribers who do not carry out work off-site;
b) Residential subscribers teleworking at home;
c) Mobile subscribers, low to moderate speed;
d) Mobile subscribers, high speed;
e) Small to medium-sized businesses;
f) Big national businesses (multi-sites);
g) Multinationals.

Each segment needs a different development scenario and different services, with different traffic needs and different quality of service requirements.

3.1.6. Summary

As a summary most telecommunications companies adapt the discussed process into few steps in the form of a life cycle. The following example is for Business Networks of Arizona [2]:

Step 1: Analyze your business requirements and current systems and identify your need to integrate information from various areas of your company.

Step 2: Construct a solution that addresses the information needs of your company. Examine possible applications and the ways in which they interface with one another. Select the correct software, hardware, and network to allow for future growth and other changing requirements.

Step 3: Implement a solution in a timely manner, with the least disruption to your company's daily operations.

Step 4: Invest in training your people. Help them to assimilate your new systems into a more productive technique of managing your company.

Step 5: Plan for ongoing support. Maintenance of equipment, network software and application updates are required at the minimum. Take a proactive approach to adapting your network computing system to your changing business environment.

3.2. The Internet

3.2.1. Introduction

The Internet has been defined in several ways by different people, but the bottom line is that: "*the Internet is probably the best known service infrastructure but at the same time the least understood*" [5]. This may be caused by the fact that in comparison with the telephone network (PSTN), the Internet is experienced by the user through the end-user terminal (computer, PDAs, mobile handsets, laptop, etc), with the user only aware of a dial-up connection or a LAN connection. In case of a private user the must be a subscription to the Internet Service Provider (ISP). In contrast the telephone network has a real existence: evidenced by public and private telephones, visible overhead lines, microwave towers, satellite dishes, exchange buildings, poles, maintenance personnel, etc [5]. The Internet is more or less the same as the public land mobile network (PLMN) often called cellular phone networks, in the sense that users of PLMN are usually aware of their mobile handsets and the immediate base transceiver station (BTS) plus its red and white tower masts. From the BTS, it's not obvious how communications occur, except that users will be aware of the cellular phone company from which they have subscribed. But in the case of the Internet most users rely on the company Internet and have no idea who their service provider is. Only private Internet users are aware of their service providers because they have to subscribe to that provider and pay a monthly fee.

In most cases the Internet is referred to as a network of networks, either big or small, all forming a single virtual and global network used for communication

and sharing of resources. Several definitions have been adopted of the Internet including the following:

a) Derived from ***Internet***working – is a packet-oriented global network formed by the interconnection of thousands of subnetworks that all make use of [4]:

- The TCP/IP protocol suite, and
- A common address structure

b) A world-wide interconnection of networks operating to Internet standards functioning as a single, large virtual network, providing characteristic services including: e-mail, file transfer, remote login, web browsing and e-commerce. Internet consists of a large number of ***inter***connected ***net***works, with each network being autonomous. [5]
c) The Internet is a global web of interconnected computer networks. It is a network of networks that link schools, libraries, businesses, hospitals, federal agencies, research institutes, and other entities into a single, large communication network that spans the globe. [10]

3.2.2. Characteristics of the Internet

The Internet has several attributes most of which make it very attractive to most network operators and users, including the following [4]:

a) Global Presence – the dream of making the world a single place has been accelerated by ICT initiatives especially the Internet, which has virtually eliminated all geographic boundaries but in the most cost-effective manner. This global presence has made access to useful academic, research and other information just a click away.
b) Attractive Applications – the global presence and accessibility is enhanced by the attractive applications that the Internet offers to several users (including companies, businesses, individuals, institutions, etc). All these applications fulfill a particular and genuine need. Several applications include: e-mail, information retrieval (WWW), e-commerce, file transfer, e-banking, entertainment, etc.
c) Every man's property – web browsers and the simplified graphical user interfaces (GUI) have made the Internet easier to use by most people as long as they have the required equipment. "*Today, the Internet can be used by just about anyone, and many regard this as the main force now driving expansion*" [4].
d) Reasonable Pricing – compared with PSTN and PMLN calls, Internet calls are reasonably priced especially for long distance calls. This is one of the reasons of adopting voice over IP (VoIP) calls as opposed to traditional PSTN or PLMN calls. As an example computer to computer VoIP calls are free no matter the distance. Most employees use the Internet for free at

their work places, but telephones usage is paid for by these individuals. Five (5) Maluti buys the user thirty (30) minutes of Internet usage in most Lesotho Internet cafes but for the same 30 minutes a user would have paid about M300.00 if making an international call by PSTN and even more if using PLMN.

e) A Global Resource – in the form of information, knowledge and communications. But this has both the good and the bad site. The good site – global access to useful information drives economic growth and development in most countries and improves the levels and standards of education and provides access to useful medical and entertainment information. The bad site – information on the Internet also includes terrorism training and extremist methods, child pornography, suicidal methods, organized crime, money laundering, etc.

f) Success factors – the main reason for networks is to satisfy a clear need from customers in terms of services offered, mainly teleservices. A teleservice should [4]: satisfy a real need; be sufficiently low priced; have sufficient coverage; be user friendly; be reliable and exhibit high availability. The first four requirements and global access make the Internet the winner. Information is a basic need in every country whether democratic or not and every individual needs information for decision making. Internet prices are extremely low in comparison to PSTN and PLMN; number of installed computers keep increasing exponential every year (from 1 million hosts in 1992 to 10 million hosts in 1995 and 140 million in 2002 [5], 2008??); access bandwidth is increasing (NUL has just upgraded from 1Mbps to 4Mbps in July 2008); user-friendliness provided by web browsers and GUIs.

3.2.3. History of the Internet

The Internet originated from experimentations surrounding packet switching of data traffic during the 1960's [4, 5, 10, 11], financed by the Advanced Research Projects Agency (ARPA), an office of the United States Department of Defense. This proves the long held believe that "*war is the mother of all technological innovations*". First experiments were performed in 1966 and first communications terminals were put into operation in 1969 [4, 5, 10, 11]. The original network that gave rise to the Internet was called ARPANET [4, 5, 10, 11], which had four nodes then. In the early 1970's, more and more people became convinced that packet switching was an efficient and dependable method of data transfer. Several projects employing packet switching were started, with Hawaiian Aloha project, the most celebrated. The technique used for the Aloha project was developed into what is now called the Ethernet – a technique now used to carry Internet traffic especially in local area networks. In 1974 [5], the basic Internet protocols TCP and IP were developed and were selected for ARPANET in 1982 [5]. The key aim of these protocols was to provide for a dynamic and robust

military network that would withstand and continue to function even if several nodes were destroyed as a result of a nuclear assault. From the aim of linking various military research organizations together, the network developed and broadened to include communications between universities, and now is a commercialized global network open to everyone.

3.2.4. User Services

As has been emphasized in this manual, the purpose of any network is to satisfy a particular need of the user (consumer or customer) by offering a certain service. The Internet has several services that it offers to different users whether individuals or businesses. The most widely used services are e-mail and information retrieval (WWW), but as the saying goes: "*there is something here for everyone*" [4]; hence several other services are now available on the Internet and other keep emerging on a daily basis.

3.2.4.1. Original Services

After its inception, the services developed were aimed at taking advantage of several possibilities presented by a network of several computers as opposed to stand-alone computers. The immediate services were those that involved resource sharing and exchange of messages [4]. Basic applications from this were the following [4, 5]:

a) Electronic mail (e-mail) – one of the original and today's most used Internet teleservice, involves the exchange of messages between two or more computer users. E-mail is based on two protocols namely: simple mail transfer protocol (SMTP) and post office protocol (POP).
b) File transfer – aims to provide a number of users with the possibility of sharing common storage resources from which files can be retrieved. The user may be required to identify themselves and obtain authorization in the form of username or password. Protocols use for file transfer are file transfer protocol 9FTP) and trivial file transfer protocol (TFTP). The FTP protocol has two parts as follows [5]:

    - Protocol Interpreter (PI) – handles the exchange of FTP commands and replies; and
    - Data Transfer Process (DTP) – establishes and manages the data connection.

c) Remote login – enables the user to connect to remote computers and use their resources. The application for this service is TELNET.

3.2.4.2. Discussion Groups

In additional to the original services, the Internet has evolved to enable users to adopt and use new services such as discussion forums. In the case the Internet

has become a platform where people with common interest can meet and discuss issues regardless of their geographical locations. These forums may be in the several forms including the following [4]:

a) News Groups – forums used for debate and exchange of information on different subjects, ranging from politics to religious issues. These forums are not based on the real-time communication, but users submit articles and other users respond at their own time. Such forums may include: class discussions, topics, etc. Though discussions of this manner are useful, they have lost focus recently with most people using it to voice their displeasure about other individuals thus turning forums into hate, gossip and propaganda forums. The transfer of information to and from discussion-group members is facilitated by the network news transfer protocol (NNTP).
b) Chat – a form of discussion forum, which enables members to communicate via short text messages. It is based on real-time communications, as there has to be a channel created between the communicating parties. It is based on Internet relay chat (IRC).

3.2.4.3. Information Retrieval

One of the modern and most used forms of the Internet is the World Wide Web (WWW). Though wrongly used synonymously with the Internet, *WWW is a component of the Internet that presents information in a graphical interface*. *Thus, www is the illustrated version of the Internet, and the easiest to use. From WWW, one can retrieve documents, view images, animation, and video, listen to sound, speak and hear voice, and view programs that run on practically any software in the world*. The enormous amount of information (albeit bad and good) on the Internet has made information retrieval or WWW attractive and less attractive at the same time [4]. Search engines [4] such as Google, Yahoo and MSN greatly facilitate information retrieval. They help locate and retrieve the desired type of information from huge amounts of information either using the titles, uniform resource locators (URL), key words and phrases.

3.2.4.4. Commerce

Commerce is the discipline concerned with buying and selling of goods and services. So, with the development of the Internet the traditional activities of commerce have now been conducted over the Internet – a concept called electronic commerce (e-commerce) [4, 5]. With e-commerce, national boundaries are no longer necessary as users can easily buy and sell their goods and services and perform all other necessary transactions over the Internet as well. Several problems with e-commerce include customs and value-added tax issues plus other legislative issues which differ from country to country. With e-commerce,

several applications including paying bills online, Internet banking, etc have been realized.

3.2.4.5. Telephony

Recently Internet has been used to transmit voice, with applications such as voice over IP (VoIP). The problem with transmitting voice over the Internet is that: the Internet is the best-effort [5] packet-based network with no guarantee of delivery, delay and packet loss. The end result is the poor quality of the voice when using Internet telephony. However several advances have been made to adapt the Internet to suit voice communications, including the introduction of additional protocols such as real-time transfer protocol (RTP), reservation (RSVP) protocols, etc. In addition to quality issues, VoIP is still illegal in most countries – legalized in South Africa by 2006 and only Telecom Lesotho is allowed to implement it in Lesotho. There are still no common standards existing for telephony over the Internet at present thus forcing communicating users to install the same software for communications to occur. The offering of voice over the Internet, which was incepted mainly for data services, is one form of ***convergence*** and VoIP is one of the major drivers of convergence and the generalized concept of next generation networks.

3.2.4.6. Multimedia Services

Multimedia is defined as [1, 4]: *a service which contains at least two of the three service types – voice, data and video, and which provides a certain degree of interactivity*. Though most traffic on the Internet still comprises data, the transmission of sound and video is increasing, with the following examples [4]:

a) Videoconferencing – the same application as telephone conferencing except that images are shown as well. High quality videoconferencing requires at least six (6) times the bandwidth of ordinary telephony [4] and is best run over the intranet, which is approximately 10 – 100 times greater than the Internet.
b) Video Transmission – video requires a lot of bandwidth which is not reserved on the public Internet and has to compete with all other traffic types for the bandwidth thus reducing the quality of the video. However, when transmitting video, multicast backbone (Mbone) and streaming video are used.

    - Multicast backbone – a logical, broadband network that is superimposed on the ordinary Internet network and consists of a number of servers that support multicast. However, most Internet routers are meant for uni-cast traffic and do not understand IP multicast. They can be used for Mbone traffic if the traffic is encapsulated in normal TCP packets by means of special Mbone computers [4, 10]. Multicasting is a one-to-many transmission, like

a conference call, while uni-casting is a one-to-one transmission, much like a private call between two parties.

- Streaming video – a technique that employs a high degree of video information compression and display of information at the receivers' concurrent with the transfer of subsequent information. The flow is smoothed by a buffer in the receiving equipment [4].

Exercise:
Investigate how the Mbone network and video streaming technique operate. After understanding the two study how the famous video sharing site – YouTube – operates and determine if it makes use of the above.

3.2.4.7. Business Services
In addition to e-commerce applications, businesses also employ Internet and Internet technologies in various ways for their businesses, including the following [4, 10]:

a) Intranets – is an internal-use, private network within an organization that uses the same kind of software (web browsers) that would also be found on the public Internet, but that is only for internal use and is usually protected by a firewall. Because of its use of the Internet technology and WWW techniques, intranet provides several benefits such as:

   - Information retrieval from company databases
   - Distribution of company news
   - Sharing of scarce resources

b) Extranet – an extension of the intranet by offering limited access for certain individuals outside the organization (such as customers, partners, subcontractors, suppliers, etc) to information available on the intranet.
c) Virtual private networks (VPN) – a private network for a company provided over the public Internet, and is often referred to as "*public intranet*". Internet service providers are able to offer better quality of service (QoS) via a VPN than on the public Internet.

3.2.5. Internet Service Providers (ISP)
For end-users to connect to or gain access to the Internet they have to meet the following requirements:

a) Subscription to the Internet Service Provider (ISP) – companies that sell Internet connection e.g. Telecom Lesotho, LEO, Comnet, Data Com, etc.

b) Connection to the ISP – either through a MODEM (telephone lines), or dedicated (leased) lines like Digital Subscriber Line (DSL), etc, provided by Telecom Lesotho; or Vodacom Lesotho's 3G HSDPA service, etc.
c) A computer with a web browser installed on it.

In the case of the National University of Lesotho (NUL), Internet subscription is with TENET [6] via Telkom SA [7] and Telecom Lesotho [8] rented lines (leased lines), paying monthly fees to these companies for Internet services and the rental of lines. Computers used on campus mainly have Internet Explorer (IE) installed and few have Firefox or Opera web browsers. The connection on NUL campus is mainly through local area network based on Ethernet and one wireless Internet access at the Thomas Mofolo Library. NUL is said to be utilizing private Internet services, because it does not buy Internet services from Lesotho, i.e. deals with the foreign ISP [9].

An Internet Service Provider (ISP) [4, 5, 10] is any organization or company that offers or sells Internet access and provides its subscribers with access to one or more Internet services and ISP's network is shown as figure 3.3. ISPs can be grouped in several categories based on [4]:

a) Types of services they offer;
b) Whether they own their own core networks or not;
c) Size of their core networks;
d) Whether they are commercial or public companies.

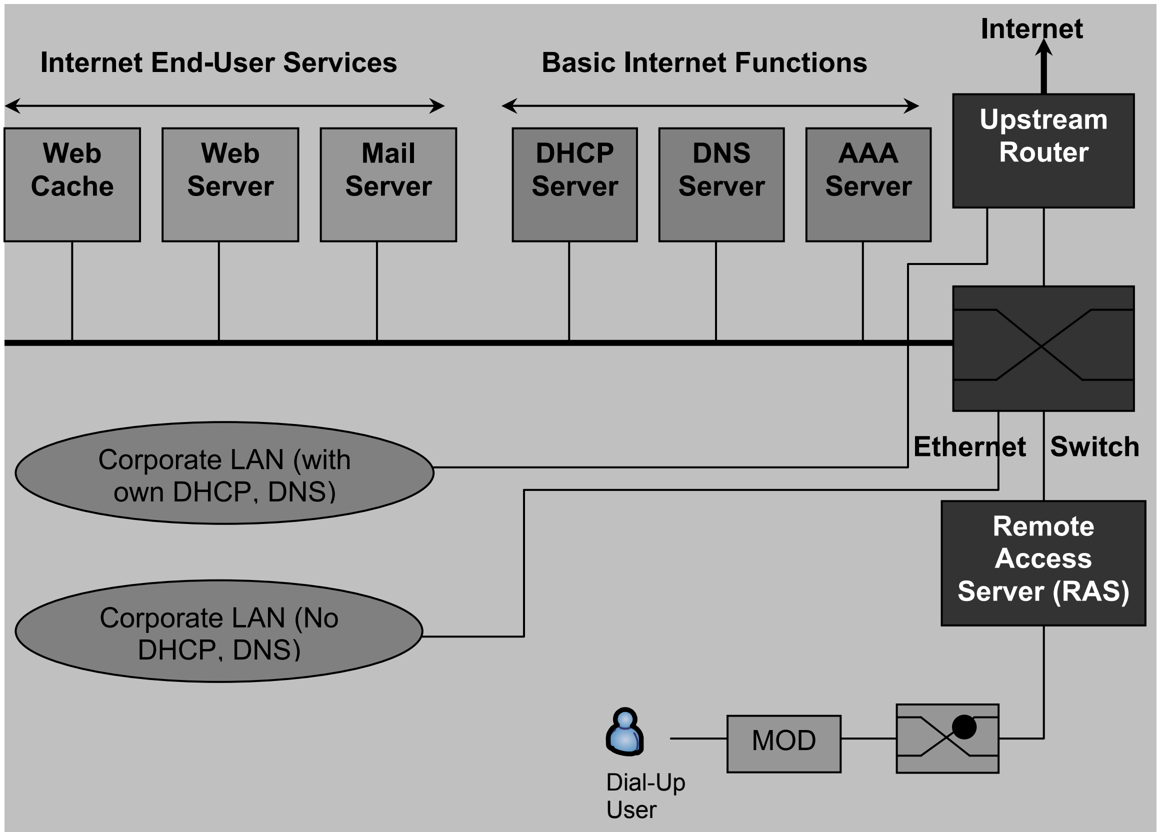

Figure 3.3 [5, 10], shows an architecture of Internet Service Provider's network

From figure 3.3, the first user or subscriber is the dial-up user, who connects to the Internet though a modem (modulator-demodulator) – which connects computers to the network through telephone lines and translates signals from analog to digital and vice versa. From the modem the telephone line is connected to PSTN exchange and then to the point of presence (PoP) provided by the remote access server (RAS). An ISP performs the following core functions for a dial-up user [5]:

a) Provides access to the Internet at the point-of-presence (PoP);
b) Provides an IP address to the dial-up user, usually leased for a time or the duration of the connection;
c) The ISP has a router connected to the Internet (upstream), which enables the dial-up user to connect to the Internet.

A PoP is identified by an IP address on the Internet side and an E.164 number on the PSTN side. The PoP gives data link layer connections to users via modems or ISDN lines. The PoP aggregates dial-up and ISDN users into a stream of IP packets. PoP is often implemented within the RAS, which performs a number of functions including [5]:

a) Terminates analog modem and ISDN B-channel connections;
b) Multiplexes upstream packets toward the ISP LAN;
c) Routes downstream packets, that is performs the mapping between destination IP address and the physical address;
d) Starts the PPP session with the user host, and gets username and password from the user;
e) Queries the AAA server, for example using the RADIUS protocol, to authenticate the user;
f) Issues IP address to valid user, relating it to the circuit address and performs packet filtering as required.

RADIUS stands for ***r***emote ***a***uthentication ***d***ial-in ***u***ser ***s***ervice [10], and simply a service or protocol that authenticates and authorizes dial-up users. From figure 3.3, a RADIUS server, though not shown, is attached to the network as a third-party authentication service. Remote users dial into the access server (RAS), and the access server requests authentication services from the RADIUS server. The RADIUS server authenticates users and allows them to access resources. The access server is essentially a client to the RADIUS server [10]. On the upstream side of the RAS, the ISP has a LAN, often called an ISP backbone, created by means of an Ethernet switch. The ISP backbone hosts a number of servers, but the three basic functions must be provided as follows [5, 10]:

a) Authentication, Authorization and Accounting (AAA) – authenticates (***verifies***) the user with the username and the password and then authorizes (***assigns resources***) the user to access other ISP facilities and the Internet, at the same time recording all usage data for billing and charging purposes.
b) Dynamic Host Configuration Protocol (DHCP) service – automatically assigns the end-user host configuration parameters such as IP address, subnet mask, default gateway, DNS server, lease period, etc.
c) Domain Name Service (DNS) – an Internet standard that allows a host to find the numerical address of the domain containing a target host.

The ISP may also offer optional supplementary services such as mail server, web hosting, etc. As shown in figure 3.3, there are two other ways of accessing the Internet in addition to dial-up. A company may own their own DNS, DHCP and AAA and simply connect to the ISP’s upstream router without going through the ISP backbone, by using leased lines or other connection methods. Or in the case of small companies, which don’t have their own DHCP, DNS and AAA; connection is to the ISP’s Ethernet switch, thus going through the ISP’s backbone before connecting to the Internet. The content on the Internet is not from the ISP, but from several organizations such as universities, companies, individuals, societies, etc; which offer large amounts of information over the Internet, and are

called content providers or information service providers [4]. With this in mind ISPs are not held liable for the content passing through their networks, but several of them have decided to block certain content such as child pornography.

Exercise:
Investigate how NUL gets connection from TENET as its ISP.

3.2.6. Architecture of the Internet

The Internet's structure can be viewed in different ways but the key is that it is a network formed of several interconnected networks – each with its own routing and management – usually called autonomous networks. This network has a global presence and acts as a universal virtual repository for information and eliminates all geographical boundaries. Figures 3.4 and 3.5 show different ways in which the Internet can be structured.

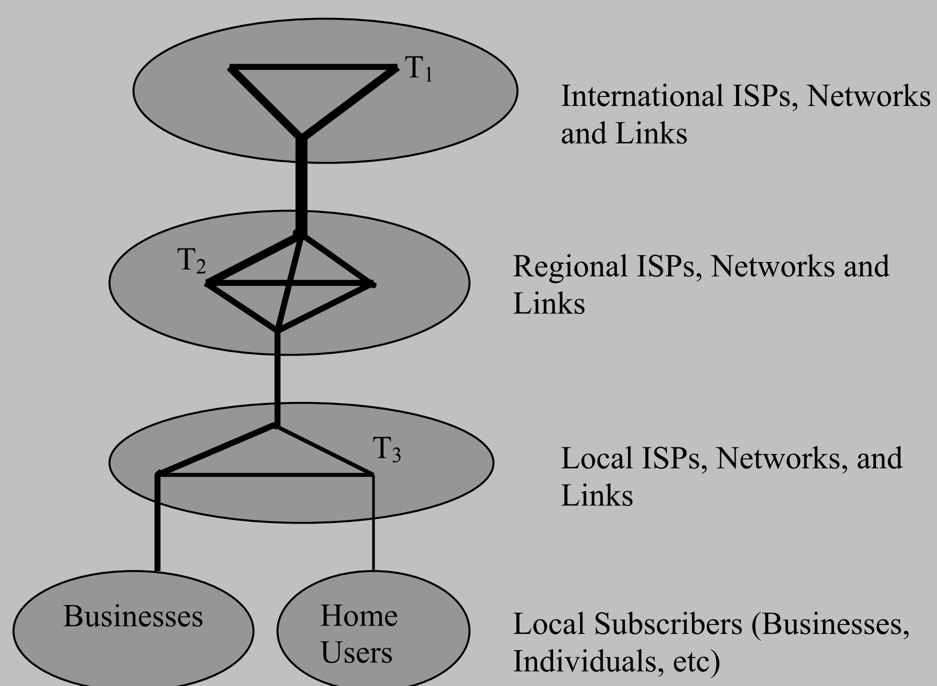

Figure 3.4 [10], shows how the Internet can be structured based on regions

From figure 3.4 the bottom stakeholders include organizations, businesses, and individual home users (residential users) who connect to local ISPs (***Tier 3 ISP***), through gateways (routers) at edge of the corporate networks and ISPs and though PoP at the ISP if a user relies on dial-up connection. These users buy Internet services from these local ISPs. In the case of Lesotho, local ISPs include Telecom Lesotho, Comnet, Datacom, etc. These companies source Internet from

regional ISPs and sell it to local customers, such as banks (Standard Lesotho, Nedbank, etc), government departments, etc. The only exception in Lesotho is the National University of Lesotho [9], which directly sources Internet services from a South African provider – TENET. But the connection to NUL is still through Telecom Lesotho's data pipes – the always down fiber link. Local ISPs are connected to regional networks with data pipes (leased lines) that are "***fat***" [10] enough to handle all the traffic produced by the ISP's subscribers. Regional ISPs (***Tier 2 ISP***) include all the South African Internet service providers, such as Telkom SA, Internet Solutions, MWeb, TENET, etc. These regional networks are connected to the international backbone network, which has even bigger data pipes. The international ISPs (***Tier 1 ISP***) include companies like Sprint in the US, etc. Though not clearly shown in figure 3.4, Tier 1 ISPs are the central component of the whole Internet service business and connect amongst themselves and treat each other as equals. Example tier 1 ISPs include: Sprint, AT&T, UUNet technologies, BBN/Genuity, MCI, PSINet, etc [10, 11]. Tier 2 ISPs connect amongst themselves and to one or more Tier 1 ISPs, and act as customers of Tier 1 ISPs, as they pay for connectivity to the rest of the Internet. Tier 3 ISP is in turn the customer of Tier 2 ISP and pay for connection to the rest of the Internet. They act as the last hop (access) network closest to the end-user systems. In Lesotho local ISPs are further classified as follows [12, 14]:

a) Class A – authorized to source international Internet bandwidth, sell to ISPs and directly to customers either deploying their own infrastructure, or through infrastructure leased from third parties;
b) Class B – authorized to source international Internet bandwidth and sell to ISPs only, either by deploying their own infrastructure or infrastructure leased from third parties; and
c) Class C – authorized to resell Internet services to clients but not allowed to own public infrastructure in the form of international links and backhaul links to provide services.

As of end of March 2007, there were six (*6*) Internet service providers (ISPs) registered and licensed by Lesotho Communications Authority (LCA) in Lesotho; with two thousand six hundred and thirty-five (*2,635*) Internet subscribers [13].

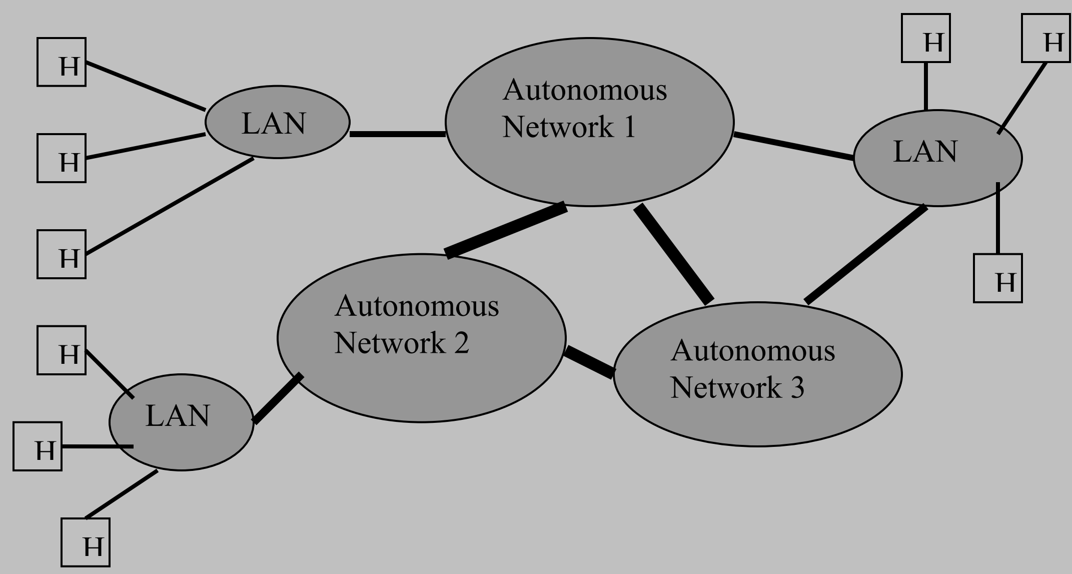

Figure 3.5 [4, 5], shows Internet structure based on AS and Hosts

When compared with figure 3.4, figure 3.5 shows the Internet as a flat structure as opposed to the hierarchical one. In addition it does not show the provision of the Internet by service providers in different regions. From figure 3.5, the principal elements of the Internet are shown as hosts, autonomous systems and local area networks. Any end-user terminal that connects to the Internet is called a host, regardless of whether it has a server role or a client role. Servers act as information repositories on the Internet and clients access such information though the exchange of messages in form of request and responses. These end-user terminals may be in several forms including computers, workstations, PCs, personal digital assistants, cellular phones, television sets with set-top boxes, laptops, etc. All hosts on the Internet have a unique identifier in the form of an IP address (***196.24.0.5***) and a name, such as ***thebe.nul.ls***. In most cases names are public, while IP addresses are not known publicly, but there is a service called DNS, which translates between the two, thus enabling users to only remember the names. Companies or individuals gain access to the Internet through several access technologies and networks, including the following: LAN, wireless access, 3.9G (HSDPA from VCL), 2.5G-3G (EVDO from Telecom Lesotho), dial-up access, cable TV, digital subscriber line (DSL) plus its derivatives (xDSL), power line communications (PLC), etc. In between the local area networks exist the autonomous systems (AS). Autonomous systems simply signify that each of these networks has its own routing technology (usually a single routing protocol) and is administered by a single authority [5]. In between the autonomous systems, transmission is provided by various bearer networks and transport systems, which might include: fiber cables, microwaves, satellites, SDH, PDH,

ATM, etc. Though not shown in figure 3.5, there are internetworking devices in between the autonomous networks, in the form of routers. Routers operate at the network layer of the OSI reference model and are known as the technology behind the Internet, and simply route the packets based on the network layer addressing (IP addresses) and do not understand the content, hence it's not possible to use ordinary routers to filter Internet traffic based on content.

3.2.6.1. Internet Backbone

Internet backbone simply defines the core area of this virtual network formed by combining several networks. Since the core carries all the traffic that traverses any particular network, it has to have high capacity and employ several tunneling and multiplexing techniques. The original ARPANET became congested by 1985 [10] and the National Science Foundation (NSF) built the network called NSFNET [10, 11], which connected six (*6*) sites with ***56kbps*** lines. TCP/IP was used to glue things together and to provide routing of traffic through gateways now called routers – the technology behind the Internet. NSFNET formed a core to which other regional networks could connect. From 1987 to 1990, the links were upgraded to T1 (1.544Mbps) lines, and management was passed over to Merit [10]. During the early 1990's [10, 11], NSF commercialized the network and allowed private companies to fund and support the network. NSF helped Merit, IBM, and MCI to form ANS (*Advanced Network and Services*), which took control of NSFNET and eventually upgraded the backbone to run at DS-3 (***45 Mbps***).

By 1992, NSF had defined a new architecture that would supersede NSFNET. The new network was to consist of the following features and components [10]:

a) **Very high speed Backbone Network Service** (vBNS) – A network that would provide ***155 Mbps*** of bandwidth to connect supercomputer centers, research facilities, and educational institutions. The network was meant for research and educational traffic; assigned to MCI in 1994.
b) **Network Access Point (NAP)** – Four regional NAPs were required to provide a connection point and traffic exchange facility for regional networks and network service providers. A NAP provides either high-speed switching or shared LAN technology that allows multiple providers to exchange traffic. Contracts assigned to Sprint, MFS, Ameritech and Lucent.
c) **Network Service Provider (NSP)** – required to connect to three of the NAPs and provide connections for regional networks that support research and education.
d) **Routing Arbiter** – provides master routing tables for all the routers connected to the NAPs and other Internet exchanges, thus eliminating the need for routers to exchange routing information with every other router. Contract assigned to Merit.

NAPs are Internet exchange points. ISPs connect into these exchange points to [10]:

- Exchange traffic with other ISPs (called peering); or
- Sell transit services to other ISPs.

Transit services are used by smaller regional and local ISPs who need to send traffic across a national ISP's network. Internet exchanges provide layer 2 switching services which means that no routing takes place; even though, ISPs connect their routers directly to the Internet exchanges. The general agreement among NAP users is that they exchange routing information and that traffic passing through the NAP is not filtered, examined, or tampered with. In the late 1990's the Internet backbone links speeds were at 1Gbps [11] and keep increasing on a yearly basis, with potentially unlimited bandwidths provided by fiber technologies.

3.2.6.2. Internet Dependence on PSTN and other networks

Most Internet users subconsciously naively think that the Internet exists in isolation. But in actual fact the Internet makes heavy use of the public switched telephone network (PSTN) infrastructure as shown by figure 3.6.

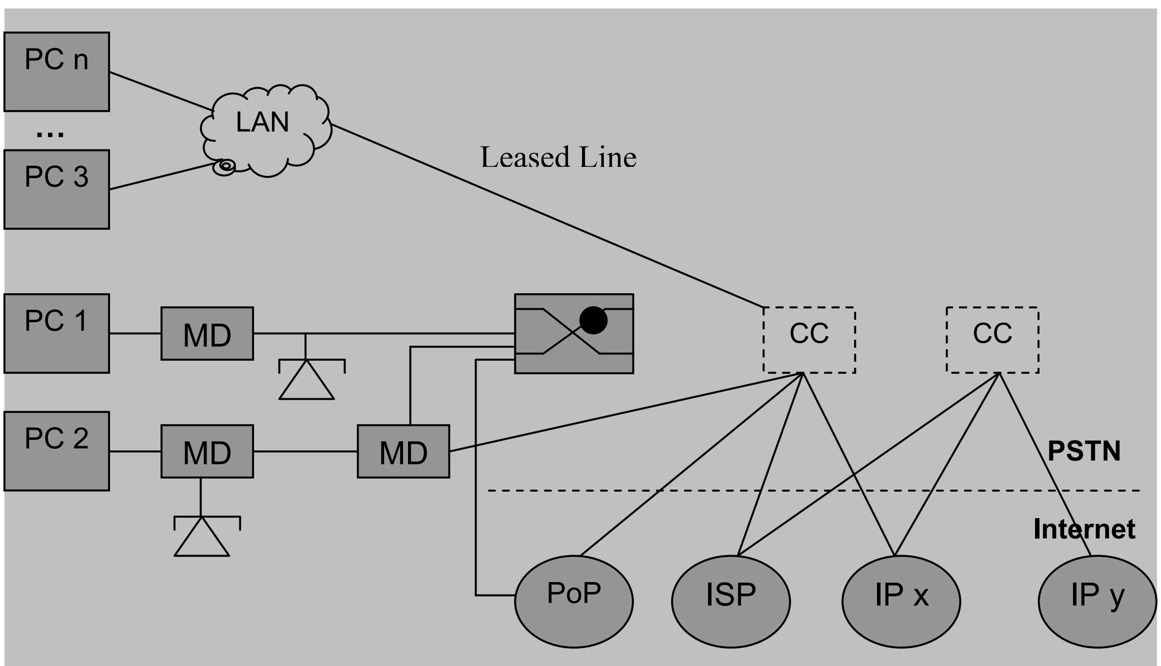

Figure 3.6 [5], shows the Use of PSTN in Internet Provision

From figure 3.6, it is clear that without the PSTN Internet provision would be difficult and would require major investments from the ISPs, and customers alike. But PSTN has enabled residential customers to simply purchase a modem and enjoy Internet connection through the use of ordinary telephone lines

(copper cables), which are available in most residences. Users dial-in to the ISP's site and enjoy Internet connection. In addition higher bandwidth users can use digital subscriber technologies and derivatives (xDSL) to obtain access. DSL plus its derivatives still rely on the copper cables (telephone lines) though they offer an always on connection as opposed to dial-in services. Even business users can use xDSL and other forms of leased line services, still offering an always on connection to the Internet. Connection of different LANs and other autonomous systems that form the Internet is still through the use of PSTN's fiber cables, satellite services, etc. On top of that Internet traffic is transported over PSTN infrastructure in the core network. A typical example is the case of NUL, which subscribes to TENET [6] for Internet services, but gets these services and traffic through Telecom Lesotho [8] and Telkom SA [7] leased data pipes. The reliance of Internet traffic and services over PSTN is viewed as one instance of ***convergence***.

On top of its reliance on PSTN, Internet provision can also be though the use of power lines, termed power line communications (PLC), or broadband over power lines (BPL). This is also one form of ***convergence***. Recently with the introduction of data services over the public land mobile network (PLMN) starting from 2.5G's general packet radio service (GPRS), and enhanced data rates for GSM evolution (EDGE); 2.5G/3G EVDO offered by Telecom Lesotho and 3.9G's HSDPA offered by Vodacom Lesotho. As shown already in section 3.2.6, Internet relies on several access technologies for the end-users and recently wireless access technologies seem to be gaining in popularity especially in countries like Lesotho where traditional wired connections are prohibitely expensive to deploy. This dependence of the Internet on PLMN is one instance of ***convergence***.

3.2.7. Internet Standardization

The Internet exists because of different autonomous networks that are interconnected and employ open protocols and standards, thus it is not owned or controlled by an individual or any organization. Instead there are organizations and bodies involved in the standardization process and input can be from anyone, as shown by figure 3.7.

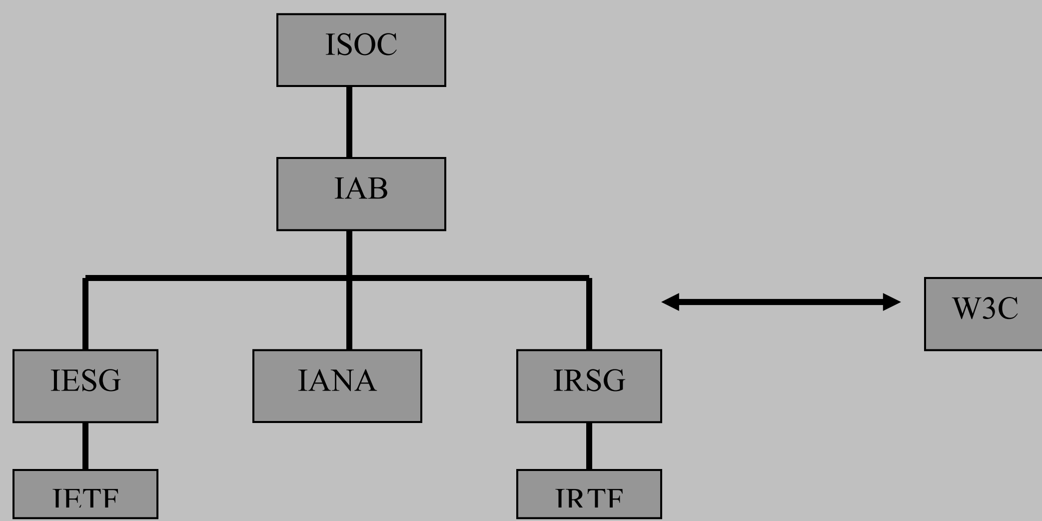

Figure 3.7 [4], shows Internet Standardization Organizations

3.2.7.1. Roles of Internet Standardization Organizations

Each of the organizations shown in figure 3.7 has different roles that it performs in regards to the standardization process as follows [4, 10]:

a) Internet Society (ISOC) - a nongovernmental international organization to promote global cooperation and coordination for the Internet and its internetworking technologies and applications. The ISOC approves appointments to the IAB from nominees submitted by the IETF nominating committee and has these objectives:

   - To maintain and develop Internet standards
   - To expand and develop Internet architecture
   - To develop effective administrative processes for the operation of the Internet
   - To promote the development of and accessibility of the Internet.

b) Internet Architecture Board (IAB) - The IAB is a technical advisory group of the ISOC. Its responsibilities are to appoint new IETF chairs and IESG candidates, serve as an appeals board, manage editorial content and publication of RFCs, and provide services to the Internet Society.
c) Internet Engineering Steering Group (IESG) - chartered by the ISOC to provide technical management of IETF activities and the Internet standards process.
d) Internet Engineering Task Force (IETF) - a large open international community of network designers, operators, vendors, and researchers

concerned with the evolution of the Internet architecture and the smooth operation of the Internet. It provides technical and development services for the Internet and creates, tests, and implements Internet standards which are eventually approved and published by the ISOC. The actual technical work of the IETF is done in its working groups.

e) Internet Assigned Numbers Agency/Authority (IANA) - acts as the clearinghouse to assign and coordinate the use of numerous Internet protocol parameters such as Internet addresses, domain names, protocol numbers, and more.
f) Internet Research Steering Group (IRSG) – functions as the decision making group for IRTF.
g) Internet Research Task Force (IRTF) – investigates subjects that are considered too uncertain, advanced or insufficiently scrutinized to be included in the standardization process.
h) World Wide Web Consortium (W3C) – develops common protocols for the evolution of the World Wide Web. It maintains vendor neutrality and works with the global community to produce specifications and reference software that is made freely available throughout the world.

3.2.7.2. Internet Documents

Before a standard can be adopted it goes through several stages of documentation. Several documents are used during the standardization process including [4, 10]:

a) Request for Comments (RFC) – a series of documents that serves as the official publications channel for Internet standards and other documentation produced by the IESG, IAB and the rest of the Internet.
b) Proposed Standard – the document will be published for the Internet world, and viewpoints will be solicited, and they remain in this form for a period of six months.
c) Draft Standard – the last stage before a specification becomes a standard, and shows that the specification is mature and useable.
d) Standard – a draft standard is elevated to the status of standard after having first been sufficiently implemented with positive operational outcome.

3.2.8. Internet Protocols

All protocols used in the Internet are part of the TCP/IP protocol suite, which was developed to solve a particular problem of "*data communication between units of the US defense research community*" [4]. This is in contrast to the more general OSI reference model, which was developed as a guide for future protocol development. Internet as part of the TCP/IP networks consists of router-connected sub-networks that are located all over the world and use packet-based

techniques to move packets between them [10]. So, the Internet adopts a connectionless communication and puts emphasis on three parties as follows [4]:

a) Processes – units communicating with one another;
b) Hosts – processes are executed in host computers (clients and servers); and
c) Networks – hosts are interconnected by the underlying networks to enable communication.

Though based on both TCP and IP, TCP is not used when communicating with the help of the TCP/IP suite, hence leading it to be named IP suite instead [4]. IP is the core protocol of the Internet and functions as follows [4]:

a) Sending IP process – sends datagrams from source to destination;
b) Routing IP process – determines the best possible path through the use of a routing protocol; and
c) Receiving IP process – receives datagrams from the destination and presents them to higher layers.

In short, IP provides a service for the transfer of data units between hosts and routers, and between routers; i.e. "*IP transport network stretches from the first to last router encountered by packets traversing the network*" [15]. It relies on a fixed length IP addresses (32 bits for IPv4 and 128 bits for IPv6), which identify both the source and the destination. IP is also responsible for the fragmentation and recombination of datagrams. With IP all packets are send individually and may take on different paths enroute to their destination. An alternative to TCP, which is connection-oriented is UDP, which is the best effort delivery protocol with no guarantees for delivery of packets. Other protocols of the Internet include [4, 5, 10, 15] : SMTP, POP, IMAP, Telnet, FTP, TFTP, NNTP, RTP, HTTP, etc.

3.2.9. Routing

The routing process simply defines the hop by hop transmission of a packet form its source to its destination, with the key aim of finding the optimal path though the Internet. The component responsible for routing is a router, which is termed a technology behind the Internet and selects best possible routes for the packets and switches the packets to the correct interfaces. The router relies on the routing table or forwarding engine in figure 3.8, when making its decisions. The routing table is build through the use of a routing protocol or control protocol in figure 3.8. The underlying protocol for routing packets on the Internet and other TCP/IP based networks is the Internet Protocol [4, 5, 10, 15].

The routing table is built up by routers exchanging reachability information with other routers by the use of a routing protocol. Routing protocols are generally divided into tow as follows [4, 15]:

a) Interior Gateway Protocol (IGP) – a mechanism for exchanging routing information among gateways and hosts within an autonomous system. Several IGP protocols include: RIP, OSPF,etc.
b) Border Gateway Protocol (BGP) – a mechanism for exchanging routing information between different autonomous systems. BGP protocols include: BGP-4, IDRP, etc.

The routing table contains information about:

a) Directly connected networks – directly connected to a router interface thus forming a static route; and
b) Remotely connected networks – not directly connected to a particular router interface. This information is found through the use of a routing protocol.

3.2.10. Management

As with other networks, the Internet has to be managed because it has become such a critical part of any business, organization, charity groups, individuals, etc. Key applications such as e-mails, file transfer, collaborative working, Internet banking, and general communications have elevated the Internet to the status of being indispensable. With this in mind, users expect the network to be dimensioned for the load it is exposed to through their sessions, while at the same time count on immediate fault-corrective action in the vent of malfunction [4]. Thus the general functions of management – Fault management, Configuration management, Accounting management, Performance management, and Security management – have to be performed. The only problem is the complexity of the Internet caused by a combination of autonomous systems. With this in mind, every service provider or network operator is at least expected to fully manage their own sub-networks or segments and ensure that individual network elements are addressable. The most common management protocol for the Internet is the simple network management protocol (SNMP), which is part of TCP/IP suite. Networks management is discussed in details in chapter 1 of this manual.

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